TECHNICAL MEMORANDUM NO. 14

LARGE AREA SPECTRAL YIELD MODEL FOR WHEAT

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREIGN AGRICULTURAL SERVICE

FOREIGN CROP CONDITION ASSESSMENT DIVISION
HOUSTON, TEXAS

LARGE AREA SPECTRAL YIELD MODEL FOR WHEAT	FIRST ISSUE

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1 REASON FOR ISSUANCE

To document and describe the use of a large area spectral yield model over the USSR. Primary development and testing done by Pat Ashburn of the Foreign Crop Condition Assessment Division, Foreign Agricultural Service.

2 COVERAGE

This Technical Memorandum describes and evaluates the operational application of the AVI Yield Model for wheat in 1979 and 1981.

3 ACKNOWLEDGMENT

Mr. Ronald Willis of the FCCAD for his support in developing the mathematical model for use in the FCCAD. His contribution is hereby gratefully acknowledged.

4 CONCURRENCE

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5 PREPARED BY:

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Pat Ashburn — Date
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PART 1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this paper is to report on the development and use of a spectrally driven wheat yield model that is derived from LANDSAT spectral data. This paper is a summary of how this model is used operationally and is not intended to show detailed research on how it was developed.

1.2 SCOPE

The scope of this paper is limited to the transformation of LANDSAT multispectral (MSS) data into a vegetation index number (VIN) that is used to derive the yield of wheat for the USSR. Also in the scope is the aggregation of the vegetation index number to the hierarchal levels of the USSR for the prime purpose of deriving a yield figure for the country.

1.3 BACKGROUND

The United States Department of Agriculture has a requirement to provide current analysis of foreign crop production. This requirement led to the establishment of a new Division within the Foreign Agricultural Service (FAS) designed to take advantage of satellite technology. This Division, the Foreign Crop Condition Assessment Division (FCCAD), is currently located in Houston, Texas. Its primary function is to monitor, assess and report on the condition of crops and agriculturaly related events in foreign countries. To satisfy these requirements, the FCCAD has developed operational capabilities including a geogridded reference data base, an interactive image processing system, and a rapid image transformation system.

The development of the vegetation index numbers in the USSR and how they are calculated are described in detail in Technical Memorandum Number 11, "Utilization of The Vegetation Index Number in the USSR," published by the USDA/FAS in Houston, Texas, in 1981[1]. This paper is intended to describe the continuation of that study and how the vegetation index number has been incorporated into the aggregation schemes developed for the geogridded data base.

Results from research on spectral reflectance and wheat yield by J. Kristian and F. J. Siddoway at the Northern Plains Soil and Water Research Center in Sidney, Montana[2], are very encouraging. Their findings of very high correlation of VINs to final yield of wheat (r^2 = .98) help provide some of the basic knowledge for the development and use of a large area procedure.

PART 2.0 THE VEGETATION INDEX MODEL FOR WHEAT YIELD

2.1 HOW IT IS CALCULATED AND USED

The Vegetation Index Model for wheat yield in the USSR is a spectrally driven yield model derived from LANDSAT (MSS) data (Figure 1). It has evolved over several years of semioperational use in the USSR for both spring and winter wheat. It has now been transformed into a simple linear equation that only requires two inputs, an average calculation for the Ashburn Vegetation Index number (AVI) and the average crop calendar stage.

The model is based on the AVI. It requires an average calculation for all the wheat located within each individual grid cell of a political hierarchy in the USSR. The average value for each 25 x 25 nautical mile grid cell is aggregated to the Oblast level by using a weighted average [Σ(number of green pixels per cell x VIN)/ Σ(green pixels)]. This provides one number for each political area, the least of which is the Oblast, and the largest, is the country level. This number is used with the crop calendar to produce a yield estimate for wheat.

The Robinson crop calendar is used to define the stage of growth for both spring and winter wheat (Figure 2). The range of stages used for calculation in the mathematical model is 1.8 (tillering) to 3.9 (flowering).

2.2 THE MANUAL MODEL

The manual model is shown in Exhibit 2 (Table 1). The manual mode also uses the Robinson crop calendar, but unlike the mathematical mode all stages are used. The numbers on the "X" axis represent the number of days from planting to harvest and also the crop calendar stage. Numbers on the "Y" axis represent the AVI value. Each of the individual curves represents a yield of wheat in quintals per hectare.

Solid lines represent curves for which reported yields were available. Dashed lines represent curves for which some yield information was reported but not enough to be sure of its exact location. By the fall of 1981 enough data had been collected to determine the exact locations of most of the curves represented in this yield model. Also a certain degree of confidence in the use of the model was obtained. A decision was made to determine the linear algorithm for the green-up side of this curve. The intent here was to see if a simple linear equation could be developed and programmed into the computer systems of the FCCAD. If so, this would allow for a very rapid turnaround of yield information from LANDSAT data. Limited results of this effort are shown in Table 5.

FIGURE 1 - VIN YIELD MODEL FOR WHEAT
(QUINTALS/HECTARES)

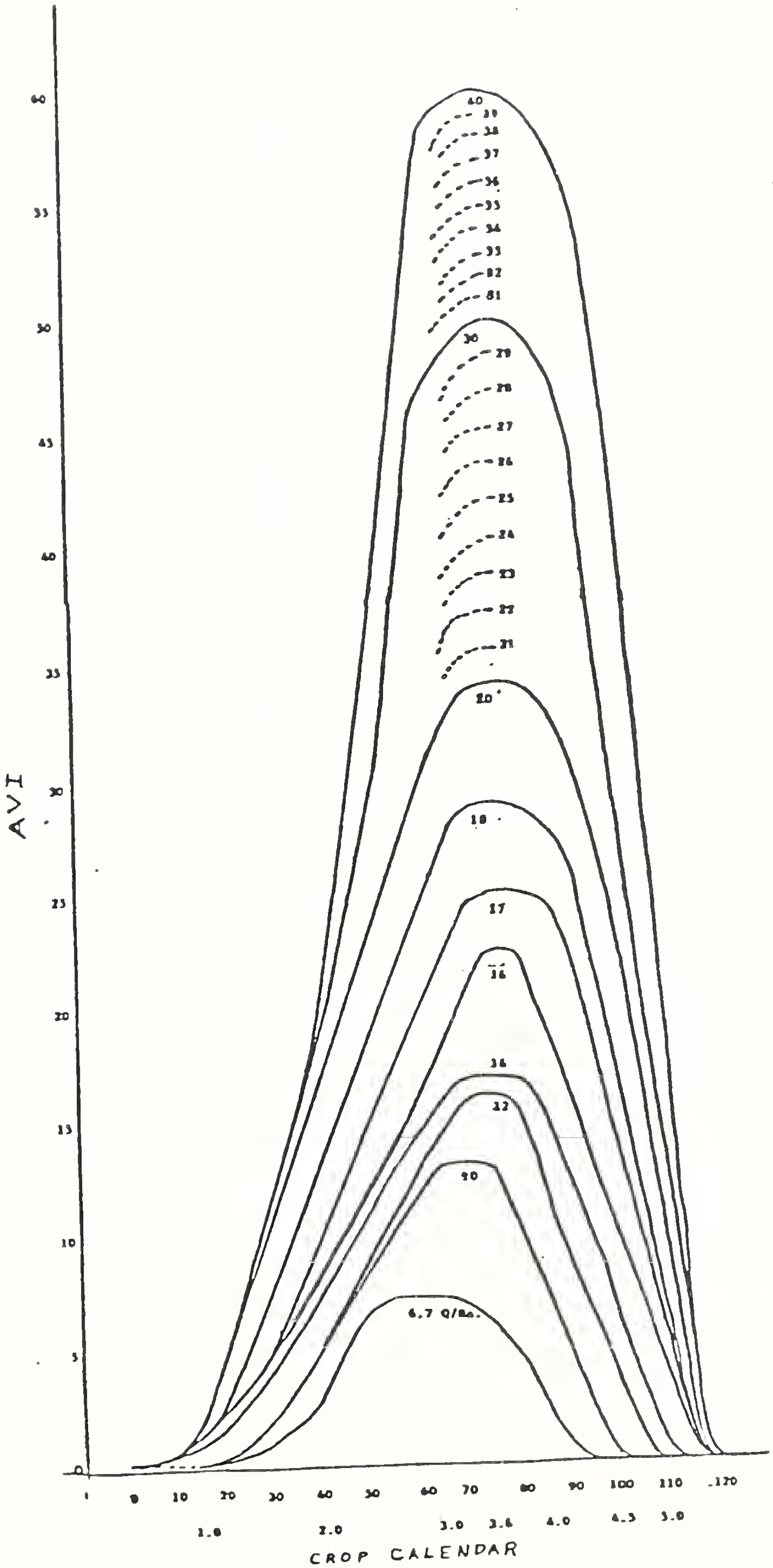

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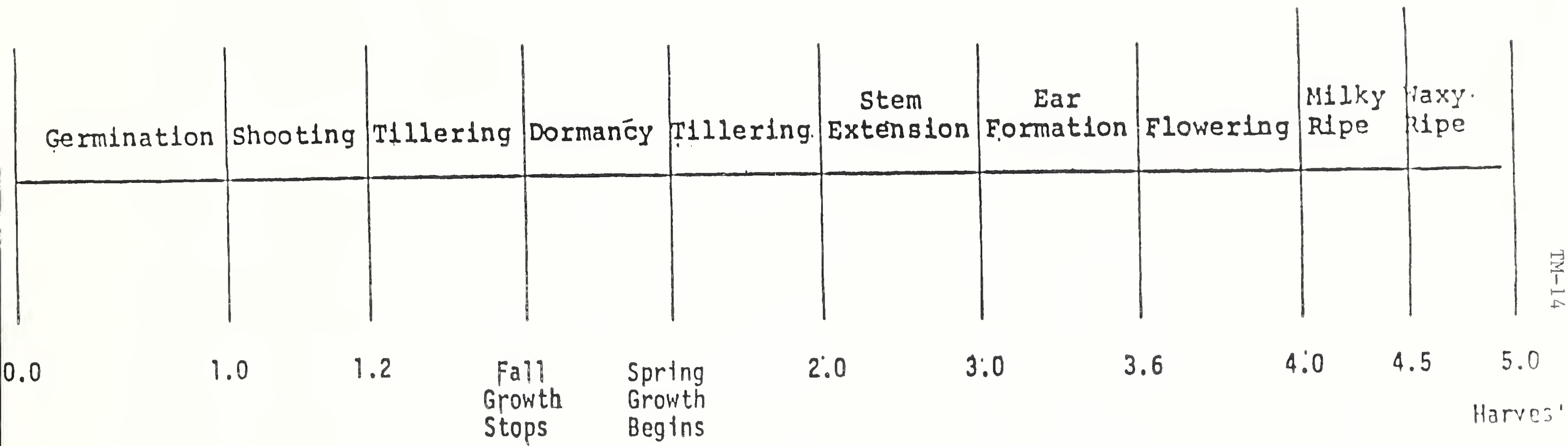
FIGURE 2 - BMTS and Phenological Growth Stages



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2.3 THE MATHEMATICAL MODEL

Table 1 shows the crop calendar (CC), the vegetation index number (AVI), and the yields (YLD) that were derived from the manual model. These values were fed into a Minitab program that provided a linear equation that explained 93.7 percent of the variation. This equation is:

$$\text{Yield} = 20.0 - 5.01X1 + 0.545X2$$

where X1 = crop calendar and X2 = vegetation index number.

The standard deviation around this regression line is 1.430 with 233 degrees of freedom. Analysis of variance provides additional information on residuals in the data, most of the variance can be explained by not being on the straight line portion of the green-up curve, but on top of the curve where the VINs are starting to flatten out (maximum green). No attempt was made to calculate this part of the curve.

TABLE 1 - THE STATISTICS OF THE VIN MODEL FOR WHEAT

THE REGRESSION EQUATION IS
Y = 20.0 - 5.01 X1 + 0.545 X2

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
	--	20.0175	0.4510	44.38
X1	CC	-5.0095	0.1932	-25.92
X2	AVI	0.5455	0.0095	57.27

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
S = 1.430
WITH (236- 3) = 233 DEGREES OF FREEDOM

R-SQUARED = 93.7 PERCENT
R-SQUARED = 93.6 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	2	7053.379	3526.690
RESIDUAL	233	476.586	2.045
TOTAL	235	7529.964	

FURTHER ANALYSIS OF VARIANCE
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN

DUE TO	DF	SS
REGRESSION	2	7053.379
CC	1	345.149
AVI	1	6708.230

The algorithm was programmed into a TI-59 calculator and used operationally during the calendar year 1981. Limited results are shown in Table 5. All of the USSR was not evaluated due to a lack of data or a lack of time to develop the data.

PART 3.0 APPROACH

3.1 THE ORBIT AND DATA

Several computer programs and procedures were developed to provide a total approach for calculating yields at the Oblast level for the USSR. These start with the VIN calculation for the individual picture element of the LANDSAT data, and end with a weighted average for the Oblast. Several pitfalls must be recognized and corrected in the use of these data and the approach. The following is a sequential step by step approach of the procedures.

Data are collected for every odd numbered orbit in the USSR during the growing season. This allows for the collection of the same spot on the earth surface every 18 days, which is a long time between data collection, especially if the area is cloud covered on the overpass day and no usuable data for the crop are collected. Also, if the area is cloud covered during maximum green, the accuracy of the VIN calculation for yield is degraded.

When clear data are sampled during the growing season for wheat, VIN masks are created for the full frames. A VIN mask is a classification map that shows the location of each wheat picture element in the scene. They are done by using the IMDACS VIN Processor. This processor does not produce an area perfect class map, but produces a vigor map. This class map or mask can often be made area perfect, given enough time and enough data.

3.2 VIGRDM

When the map/masks for wheat are created, a program called VIGRDM is used to divide the images into their appropriate grid cells (Table 2). The average VINs for each of the cells are calculated along with the amount of good data, the percent of green pixels, the names of the crops, and the date of the images. Only those grid cells that are totally within the data are stored. Consequently, out of a possible 16 cells in a full frame of data, no more than 5 are commonly stored. Therefore, the data are only samples and present all the problems encountered with sampling. However, the data calculated for each of the cells are good, and hopefully are representative of the Oblast.

3.3 VISUMY

The program used to produce an aggregated figure for the Oblast and for higher geographic levels is called VISUMY. A weighted average using the number of green pixels in each of the grid cells and their average VINs are aggregated to the Oblast level to provide one VIN for the Oblast. A simple average of the percent of green in each grid cell is taken to provide one number for the percent of green pixels in the Oblast. These two numbers provide the VIN for use in the yield calculation, and the amount of wheat acreage in the Oblast.

TABLE 2 - VEGETATIVE INDEX NUMBER GRID CELL
FOR THE MASKED IMAGE (VIGRDM)

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```
*** PROGRAM VIGRDM *** MASKED IJ CELL VIN COMPUTATION

ENTER 3-BYTE CROP MASK FILE QUALIFIER:
ENTER IMAGE FILE NAME ELSE BLANK TO QUIT.
INPUT FILES: HDR=     [70,7]V172021V0.IMH;3151  IMG=     [70,7]V172021V0.IMD;3151
IMAGE ID=V172021V0 DATE:  7 24 81 NUM CHAN: 4 NUM PIX: 510 SKIP: 5 ERTS
                                            NUM LINES: 510 SKIP: 5
CROP MASK TO BE APPLIED:      [70,7]V172021V0.WHS
FILES HAVE BEEN OPENED.
I:  298   301 J:   191   194
I:  298   301 J:   191   194
NUM IJ:      2   STANDARD CROP CODE: WHT
I=299 J=192 CORR: S SUN: 49 %GOOD=100.0 %AREA= 55.6 A 23.1 L 31.5 K  9.1
I=299 J=193 CORR: S SUN: 49 %GOOD=100.0 %AREA= 52.6 A 25.0 L 32.5 K 10.5
ENTER IMAGE FILE NAME ELSE BLANK TO QUIT.
INPUT FILES: HDR=     [70,7]V172023V0.IMH;3151  IMG=     [70,7]V172023V0.IMD;3151
IMAGE ID=V172023V0 DATE:  7 24 81 NUM CHAN: 4 NUM PIX: 510 SKIP: 5 ERTS
                                            NUM LINES: 510 SKIP: 5
CROP MASK TO BE APPLIED:      [70,7]V172023V0.WHS
FILES HAVE BEEN OPENED.
I:  303   306 J:   187   190
I:  303   306 J:   187   190
NUM IJ:      3   STANDARD CROP CODE: WHT
I=304 J=188 CORR: S SUN: 50 %GOOD= 97.5 %AREA= 78.8 A 29.0 L 30.3 K 16.6
I=305 J=188 CORR: S SUN: 50 %GOOD= 99.3 %AREA= 45.2 A 18.5 L 21.7 K  9.6
I=305 J=189 CORR: S SUN: 50 %GOOD= 99.5 %AREA= 27.6 A 15.5 L 18.9 K  7.3
```

One product from this program is shown in Table 3. In this table, special attention should be paid to the number of grid cells used to calculate the average VIN for each level of the geographic hierarchy and the date for each calculation. Also note that the winter grains masks (MGW) are separate calculations of the data. These masks, whether for winter grain, rye, or wheat, carry the numbers used in the VIN wheat yield model. Also note that only a few numbers are calculated for specific crops. Few masks were produced because of time, poor data, or the date of the data. The data elements in Table 3 are:

1. Calendar date
2. 18 day period
3. Number of grid cells used in the calculation
4. Satellite type
5. Type of crop mask
6. Sun angle correction
7. "M" for mask used
8. Percent of green pixels in the masks
9. "A" for AVI and average
10. "L" for LAI and average
11. "K" for KVI and average

Since so little time was available for producing crop maps, care must be taken to assure that a representative sample be obtained. This is not difficult when all the wheat in a given Oblast is in a similar condition, but in large Oblasts with varying crop conditions, this becomes more difficult.

No attempt was made to determine the accuracy of aggregating the number of green pixels to higher levels. This could be done but is outside the scope of this paper. The average VINs for the aggregated areas are used with the calculated crop calendar to determine the yield of wheat for each area. These are summed to the country level.

TABLE 3 - VEGETATIVE INDEX NUMBER SUMMARY (VISUMY)

```
TABLE 3 - VEGETATIVE INDEX NUMBER SUMMARY
              (VISUMY)

*** RUN OPTION *** COMPUTE IMAGE AND CROP VINS
                   AVE VINS ARE WEIGHTED BY CROP AREA OR IMG %+AVI AREA,
                   AVE AREA IS A SIMPLE AVERAGE.
GEOGRAPHIC-HIERARCHY?
PERIOD 810322 TO 810408, JULIAN DAY  81
PERIOD 810409 TO 810426, JULIAN DAY  99
PERIOD 810427 TO 810514, JULIAN DAY 117
PERIOD 810515 TO 810601, JULIAN DAY 135
PERIOD 810602 TO 810619, JULIAN DAY 153
PERIOD 810620 TO 810707, JULIAN DAY 171

 *** WEIGHTED AVERAGE ***      CROP METHOD   AREA

UR0100100101 SUMMARY: LATVIA
810427 18       4 LSAT-ACQ          S       51.5%  A=  4.9 L=  4.1 K= 12.0

 *** WEIGHTED AVERAGE ***      CROP METHOD   AREA

UR0100100102 SUMMARY: LITHUANIA
810322 18       4 LSAT-ACQ          S       19.1%  A=  2.4 L=  3.9 K= 10.4
810427 18       5 LSAT-ACQ          S       48.0%  A=  5.8 L=  6.5 K= 10.6
810515 18       7 LSAT-ACQ          S       95.9%  A= 23.7 L= 18.4 K= 20.2
810602 18       7 LSAT-ACQ          S       87.6%  A= 25.0 L= 24.6 K= 22.9

 *** WEIGHTED AVERAGE ***      CROP METHOD   AREA

UR0100100103 SUMMARY: KALININGRAD
810322 18       4 LSAT-ACQ          S       18.8%  A=  3.2 L=  3.8 K= 10.5
810427 18       3 LSAT-ACQ          S       63.5%  A= 16.0 L= 11.6 K= 16.4
810427 18       2 LSAT-ACQ    MGW   S   M   15.6%  A= 35.4 L= 33.5 K=  8.8
810620 18       1 LSAT-ACQ          S       95.8%  A= 20.4 L= 23.4 K= 32.7

 *** WEIGHTED AVERAGE ***      CROP METHOD   AREA

UR010010        SUMMARY: BALTICS
810322 18       8 LSAT-ACQ          S       19.0%  A=  2.8 L=  3.9 K= 10.4
810427 18      12 LSAT-ACQ          S       53.1%  A=  8.6 L=  7.3 K= 12.8
810427 18       2 LSAT-ACQ    MGW   S   M   15.6%  A= 35.4 L= 33.5 K=  8.8
810515 18       7 LSAT-ACQ          S       95.9%  A= 23.7 L= 18.4 K= 20.2
810602 18       7 LSAT-ACQ          S       87.6%  A= 25.0 L= 24.6 K= 22.9
810620 18       1 LSAT-ACQ          S       95.8%  A= 20.4 L= 23.4 K= 32.7

UR01            SUMMARY: BALTICS
810322 18       8 LSAT-ACQ          S       19.0%  A=  2.8 L=  3.9 K= 10.4
810427 18      12 LSAT-ACQ          S       53.1%  A=  8.6 L=  7.3 K= 12.8
810427 18       2 LSAT-ACQ    MGW   S   M   15.6%  A= 35.4 L= 33.5 K=  8.8
810515 18       7 LSAT-ACQ          S       95.9%  A= 23.7 L= 18.4 K= 20.2
810602 18       7 LSAT-ACQ          S       87.6%  A= 25.0 L= 24.6 K= 22.9
810620 18       1 LSAT-ACQ          S       95.8%  A= 20.4 L= 23.4 K= 32.7
```


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PART 4.0 RESULTS

4.1 PAST RESULTS

Past use of the manual model has provided accurate results (Table 4). These results were derived from data taken over the spring wheat area of the New Lands in 1979. The information derived from these results was used to provide some additions and revisions to the existing model. This allowed for a better understanding of the relationships between green biomass and yield. Also, relationships between the VIN and conditions existing after the index numbers were calculated were better understood.

It became very evident that additional systems were needed to determine yield detracting characteristics after the vegetation index numbers were last calculated. For instance, in 1979 some yield loss was directly attributed to a late harvest. This complicated the accuracy determination of the model, since the model for loss due to late harvest had not been independently tested.

4.2 CURRENT RESULTS

In Table 5, the Ukraine SSR, the North Caucasus Region, and Kazakhstan SSR are shown with their average VINs. The estimated yield derived from the VIN, the average VIN, and the reported yield from the USSR are shown. It is evident, from looking at this table, that little yield information is available for this past year. This hampers an accuracy determination for the model. Consequently, more time is required before enough yield data for a good evaluation of the model and the aggregation procedures are completed.

TABLE 4 - ESTIMATED SPRING WHEAT YIELDS DERIVED FROM VINS FOR 1979

OBLASTS	1970-1974 AVG. YIELD	ESTIMATED YIELD SPRING WHEAT 1979	REDUCTION DUE TO LATE HARVEST		*REPORTED YIELD IN TOTAL GRAIN
Altay	13.3	13.1			13.4
Bashkir	14.1	19.3	17%	16.0	15.9
Kemerovo	13.8	18.0	5%	17.6	
Kokechetav	12.1 (11.4)[1]	18.7	6%	17.6	14.9
Kurgan	16.0 (6.6)[1]	19.6	11%	17.6	15.0
Kustanay	9.7 (8.5)[1]	17.3	16%	14.5	14.0
Novosibirsk	13.0	19.3	6%	18.3	
Omsk	14.5	19.3	11%	17.3	17.9
Orenburg	11.5	11.0			13.5
Pavlodar	7.7 (6.6)[1]	11.0			12.2
Severo-Kazakh	14.6 (12.3)[1]	20.2	10%	18.0	18.3
Tselinograd	10.0 (9.9)[1]	15.5			17.0

*MOST OF THE CROPLAND IS SOWN TO SPRING WHEAT

[1]TOTAL GRAIN 1971-1975

TABLE 5 - VIN NUMBER YIELD AND RESULTS

WINTER WHEAT

GEOGRAPHIC AREA	AVERAGE VIN	EST. YIELD FROM VIN	REPORTED YIELD
Western Ukraine	37.5	27.1	
Donets-Dnepr	40.9	28.5	
Southern Ukraine	29.0	21.8	
Zaporozhye Oblast	47.5	32.3	32.7
Moldavia SSR	29.7	21.9	
Kransnodar Kray	48.6	34.2	
Stavropol Kray	46.8	31.8	32.8
Rostov Oblast	35.3	25.2	23.0
N. Caucasus Region	42.1	28.9	

SPRING WHEAT

Uralsk Oblast	13.6	9.3	
Turgay Oblast	20.4	15.0	
Tselinograd Oblast	21.4	15.6	
Kokchetav Oblast	20.3	16.0	
Severokazakh Oblast	18.8	16.2	
Pavlodar Oblast	7.5	7.0	
Karaganda Oblast	16.6	12.0	
Semipalatinsk Oblast	8.1	9.3	
Kazakh SSR	18.9	13.2	

PART 5.0 CONCLUSION

5.1 CONCLUSIONS

This is the first time that the VIN wheat yield model has been tested over such a large area of the USSR. And as of this writing, the results are inconclusive, mostly due to a lack of reported yield data. This does not, however, alter the past successful results of the use of the model over smaller areas of the USSR, as shown in the data from 1979. Sufficient results were obtained during 1979 and the past two years to believe that the model could be put into use on a wide scale. This of course requires that data be available, and that a sufficient number of resources be put into the classification and calculation of the appropriate VIN data for countries of interest. It seems appropriate for AgRISTARS to include the United States in a test project, so that more data for county or state size areas would be available. This activity would also help determine the exact location of additional curves within the model.

The VIN model can provide a one time capability for deriving the yield over a very large area, the best time being at or just before maximum greenness of the plant. This accounts for the accumulation of yield up to that image date but cannot account for any yield affecting events after the date. So additional data (weather) should be used to monitor any adverse effects after the last date of imagery. It is also apparent that the second component of this vegetation index number yield model, the crop calendar, be as accurate as possible.

Only time will tell how accurate the procedure and the model are for estimating wheat over large areas of the USSR. This paper has not addressed the accuracy problem, but has provided a model and an aggregation procedure with existing software that could be used as an analytical tool in other countries as well as the USSR.

GLOSSARY AND REFERENCES

AVI - Ashburn Vegetation Index Number

IMDACS - Integrated Multivariate Data Analysis and Classification System

KVI - Kauth Vegetation Index Number

LAI - Leaf Area Index Vegetation Index Number

MASK - A Classification Map of Nonthresholded Picture Elements

MSS - Multispectral Scanner from the LANDSAT Satellite

VIGRDM - Vegetation Index Grid Cell Map Program

VIN - Vegetation Index Number - A numerical number that describes the greenness of the picture element

VISUMY - Vegetation Index Number Summary Program

REFERENCES

1. Ashburn, Pat, "Utilization of the Vegetation Index Number in the USSR," TM-11 (May 18, 1981), The Foreign Crop Condition Assessment Division, FAS/USDA.

2. Aase, J. K., and Siddoway, F. H., "Spring Wheat Yield Estimates from Spectral Reflectance Measurements," Northern Plains Soil and Water Research Center, Sidney, Montana, January 1, 1981.

TABLE 1 - THE STATISTICS OF THE VIN MODEL FOR WHEAT --

THE REGRESSION EQUATION IS
Y = 20.0 - 5.01 X1 + 0.545 X2

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
	--	20.0175	0.4510	44.38
X1	CC	-5.0095	0.1932	-25.92
X2	AVI	0.5455	0.0095	57.27

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
S = 1.430
WITH (236- 3) = 233 DEGREES OF FREEDOM

R-SQUARED = 93.7 PERCENT
R-SQUARED = 93.6 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	2	7053.379	3526.690
RESIDUAL	233	476.586	2.045
TOTAL	235	7529.964	

FURTHER ANALYSIS OF VARIANCE
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN

DUE TO	DF	SS
REGRESSION	2	7053.379
CC	1	345.149
AVI	1	6708.230

ROW	X1 CC	Y YLD	PRED. Y VALUE	ST.DEV. PRED. Y	RESIDUAL	ST.RES.
97	2.80	8.0000	10.9002	0.1661	-2.9002	-2.04R
146	3.00	21.0000	24.0805	0.1292	-3.0805	-2.16R
147	3.40	8.0000	8.4400	0.2372	-0.4400	-0.31 X
148	3.40	8.5000	8.9854	0.2292	-0.4854	-0.34 X
189	3.40	33.0000	31.3497	0.2359	1.6503	1.17 X
190	3.40	33.5000	31.8951	0.2440	1.6049	1.14 X
191	3.40	35.0000	32.4406	0.2522	2.5594	1.82 X
192	3.40	35.8000	32.9861	0.2604	2.8139	2.00RX
193	3.40	36.8000	33.5316	0.2688	3.2684	2.33RX
194	3.40	37.5000	34.0770	0.2773	3.4230	2.44RX
195	3.60	11.0000	9.6199	0.2387	1.3801	0.98 X
196	3.60	11.7000	10.1654	0.2313	1.5346	1.09 X
233	3.60	32.0000	30.3478	0.2293	1.6522	1.17 X
234	3.60	33.0000	30.8932	0.2366	2.1068	1.49 X
235	3.60	34.0000	31.4387	0.2441	2.5613	1.82 X
236	3.60	35.0000	31.9842	0.2517	3.0158	2.14RX

R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

-- PRINT C1 C2 C3 C5

COLUMN	CC	AVI	YLD	ESTYLD
COUNT	236	236	236	236
ROW				
1	1.80000	3.	10.0000	12.6368
2	1.80000	4.	11.0000	13.1823
3	1.80000	5.	13.0000	13.7278
4	1.80000	6.	14.0000	14.2732
5	1.80000	7.	16.0000	14.8167
6	1.80000	8.	17.0000	15.3642
7	1.80000	9.	18.0000	15.9096
8	1.80000	10.	19.0000	16.4551
9	1.80000	11.	19.5000	17.0006
10	1.80000	12.	19.8000	17.5460
11	1.80000	13.	20.0000	18.0915
12	1.80000	14.	20.0000	18.6370
13	1.80000	15.	20.2000	19.1825
14	1.80000	16.	20.5000	19.7279
15	1.80000	17.	20.8000	20.2734
16	1.80000	18.	21.0000	20.8189
17	1.80000	19.	21.5000	21.3643
18	1.80000	20.	22.0000	21.9098
19	1.80000	21.	23.0000	22.4553
20	1.80000	22.	23.5000	23.0007
21	1.80000	23.	24.0000	23.5462
22	1.80000	24.	24.5000	24.0917
23	1.80000	25.	25.0000	24.6371
24	2.00000	5.	10.0000	12.7259
25	2.00000	6.	13.0000	13.2713
26	2.00000	7.	13.5000	13.8168
27	2.00000	8.	14.0000	14.3623
28	2.00000	9.	16.5000	14.9077
29	2.00000	10.	17.0000	15.4532
30	2.00000	11.	18.0000	15.9987
31	2.00000	12.	18.5000	16.5441
32	2.00000	13.	19.0000	17.0896
33	2.00000	14.	19.5000	17.6351
34	2.00000	15.	19.8000	18.1806
35	2.00000	16.	20.0000	18.7260
36	2.00000	17.	20.0000	19.2715
37	2.00000	18.	20.5000	19.8170
38	2.00000	19.	20.6000	20.3624
39	2.00000	20.	21.0000	20.9079
40	2.00000	21.	21.5000	21.4534
41	2.00000	22.	22.0000	21.9988
42	2.00000	23.	23.0000	22.5443
43	2.00000	24.	24.0000	23.0898
44	2.20000	7.	10.0000	12.8149
45	2.20000	8.	12.0000	13.3604
46	2.20000	9.	14.0000	13.9058
47	2.20000	10.	16.0000	14.4513
48	2.20000	11.	16.5000	14.9968
49	2.20000	12.	16.8000	15.5423
50	2.20000	13.	17.0000	16.0877
51	2.20000	14.	17.5000	16.6332
52	2.20000	15.	17.8000	17.1787
53	2.20000	16.	18.0000	17.7241
54	2.20000	17.	18.3000	18.2696
55	2.20000	18.	18.6000	18.8151
56	2.20000	19.	18.9000	19.3605

-- PRINT C1 C2 C3 C5

COLUMN	CC	AVI	YLD	ESTYLD
COUNT	236	236	236	236
ROW				
57	2.20000	20.	19.0000	19.9060
58	2.70000	21.	19.3000	20.4515
59	2.20000	22.	19.6000	20.9970
60	2.20000	23.	20.0000	21.5424
61	2.40000	9.	12.0000	12.9040
62	2.40000	10.	12.5000	13.4494
63	2.40000	11.	14.0000	13.9949
64	2.40000	12.	16.0000	14.5404
65	2.40000	13.	16.3000	15.0858
66	2.40000	14.	16.6000	15.6313
67	2.40000	15.	17.0000	16.1768
68	2.40000	16.	17.3000	16.7222
69	2.40000	17.	17.6000	17.2677
70	2.40000	18.	17.8000	17.8132
71	2.40000	19.	18.0000	18.3586
72	2.40000	20.	18.3000	18.9041
73	2.40000	21.	18.5000	19.4496
74	2.40000	22.	18.8000	19.9951
75	2.40000	23.	19.0000	20.5405
76	2.40000	24.	19.2000	21.0860
77	2.40000	25.	19.4000	21.6315
78	2.40000	26.	19.8000	22.1769
79	2.40000	27.	20.0000	22.7224
80	2.60000	10.	10.0000	12.4475
81	2.60000	11.	12.0000	12.9930
82	2.60000	12.	13.0000	13.5385
83	2.60000	13.	14.0000	14.0839
84	2.60000	14.	16.0000	14.6294
85	2.60000	15.	16.3000	15.1749
86	2.60000	16.	16.5000	15.7203
87	2.60000	17.	16.8000	16.2658
88	2.60000	18.	17.0000	16.8113
89	2.60000	19.	17.3000	17.3568
90	2.60000	20.	17.6000	17.9022
91	2.60000	21.	19.9000	18.4477
92	2.60000	22.	18.0000	18.9932
93	2.60000	23.	18.4000	19.5386
94	2.60000	24.	18.8000	20.0841
95	2.60000	25.	19.0000	20.6296
96	2.60000	26.	20.0000	21.1750
97	2.80000	9.	8.0000	10.9002
98	2.80000	10.	9.0000	11.4456
99	2.80000	11.	10.0000	11.9911
100	2.80000	12.	11.0000	12.5366
101	2.80000	13.	12.0000	13.0820
102	2.80000	14.	14.0000	13.6275
103	2.80000	15.	15.0000	14.1730
104	2.80000	16.	16.0000	14.7185
105	2.80000	17.	16.3000	15.2639
106	2.80000	18.	16.6000	15.8094
107	2.80000	19.	16.8000	16.3549
108	2.80000	20.	17.0000	16.9003
109	2.80000	21.	17.3000	17.4458
110	2.80000	22.	17.6000	17.9913
111	2.80000	23.	17.8000	18.5367
112	2.80000	24.	18.0000	19.0822
113	2.80000	25.	19.3000	19.6277
114	2.80000	26.	19.6000	20.1731
115	2.80000	27.	19.8000	20.7186
116	2.80000	28.	20.0000	21.2641
117	2.80000	29.	20.2000	21.8096
118	2.80000	30.	20.5000	22.3550
119	2.80000	31.	21.0000	22.9005
120	3.00000	9.	7.5000	9.8983
121	3.00000	10.	8.0000	10.4437
122	3.00000	11.	8.5000	10.9892

-- PRINT C1 C2 C3 C5

COLUMN	CC	AVI	YLD	ESTYLD
COUNT	236	236	236	236
ROW				
123	3.00000	12.	9.0000	11.5347
124	3.00000	13.	10.0000	12.0801
125	3.00000	14.	12.0000	12.6256
126	3.00000	15.	14.0000	13.1711
127	3.00000	16.	15.0000	13.7166
128	3.00000	17.	15.5000	14.2620
129	3.00000	18.	16.0000	14.8075
130	3.00000	19.	16.3000	15.3530
131	3.00000	20.	16.6000	15.8984
132	3.00000	21.	16.9000	16.4439
133	3.00000	22.	17.0000	16.9894
134	3.00000	23.	17.2000	17.5348
135	3.00000	24.	17.5000	18.0803
136	3.00000	25.	17.7000	18.6258
137	3.00000	26.	17.9000	19.1713
138	3.00000	27.	18.0000	19.7167
139	3.00000	28.	18.5000	20.2622
140	3.00000	29.	19.0000	20.8077
141	3.00000	30.	19.5000	21.3531
142	3.00000	31.	20.0000	21.8986
143	3.00000	32.	20.3000	22.4441
144	3.00000	33.	20.6000	22.9895
145	3.00000	34.	20.8000	23.5350
146	3.00000	35.	21.0000	24.0805
147	3.40000	10.	8.0000	8.4400
148	3.40000	11.	8.5000	8.9854
149	3.40000	12.	9.0000	9.5309
150	3.40000	13.	10.0000	10.0764
151	3.40000	14.	11.0000	10.6218
152	3.40000	15.	12.0000	11.1673
153	3.40000	16.	13.0000	11.7128
154	3.40000	17.	14.0000	12.2582
155	3.40000	18.	15.0000	12.8037
156	3.40000	19.	15.5000	13.3492
157	3.40000	20.	15.8000	13.8946
158	3.40000	21.	16.0000	14.4401
159	3.40000	22.	16.3000	14.9856
160	3.40000	23.	16.6000	15.5311
161	3.40000	24.	17.0000	16.0765
162	3.40000	25.	17.3000	16.6220
163	3.40000	26.	17.5000	17.1675
164	3.40000	27.	17.7000	17.7129
165	3.40000	28.	17.9000	18.2584
166	3.40000	29.	18.0000	18.8039
167	3.40000	30.	18.5000	19.3493
168	3.40000	31.	19.0000	19.8948
169	3.40000	32.	19.5000	20.4403
170	3.40000	33.	20.0000	20.9858
171	3.40000	34.	20.5000	21.5312
172	3.40000	35.	21.0000	22.0767
173	3.40000	36.	21.5000	22.6222
174	3.40000	37.	22.0000	23.1676
175	3.40000	38.	22.9000	23.7131
176	3.40000	39.	23.5000	24.2586
177	3.40000	40.	24.1000	24.8040
178	3.40000	41.	24.8000	25.3495
179	3.40000	42.	25.3000	25.8950
180	3.40000	43.	25.9000	26.4404
181	3.40000	44.	26.5000	26.9859
182	3.40000	45.	27.0000	27.5314
183	3.40000	46.	28.0000	28.0769
184	3.40000	47.	28.8000	28.6223
185	3.40000	48.	29.2000	29.1678
186	3.40000	49.	30.0000	29.7133
187	3.40000	50.	30.5000	30.2587
188	3.40000	51.	32.5000	30.8042

-- PRINT C1 C2 C3 C5

COLUMN	CC	AVI	YLD	ESTYLD
COUNT	236	236	236	236
ROW				
189	3.40000	52.	33.0000	31.3497
190	3.40000	53.	33.5000	31.8951
191	3.40000	54.	35.0000	32.4406
192	3.40000	55.	35.8000	32.9861
193	3.40000	56.	36.8000	33.5316
194	3.40000	57.	37.5000	34.0770
195	3.60000	14.	11.0000	9.6199
196	3.60000	15.	11.7000	10.1654
197	3.60000	16.	12.0000	10.7109
198	3.60000	17.	14.0000	11.2563
199	3.60000	18.	14.5000	11.8018
200	3.60000	19.	15.0000	12.3473
201	3.60000	20.	15.3000	12.8928
202	3.60000	21.	15.6000	13.4382
203	3.60000	22.	16.0000	13.9837
204	3.60000	23.	16.3000	14.5292
205	3.60000	24.	16.6000	15.0746
206	3.60000	25.	17.0000	15.6201
207	3.60000	26.	17.2000	16.1656
208	3.60000	27.	17.5000	16.7110
209	3.60000	28.	17.7000	17.2565
210	3.60000	29.	18.0000	17.8020
211	3.60000	30.	18.3000	18.3475
212	3.60000	31.	18.6000	18.8929
213	3.60000	32.	19.0000	19.4384
214	3.60000	33.	19.5000	19.9839
215	3.60000	34.	20.0000	20.5293
216	3.60000	35.	20.3000	21.0748
217	3.60000	36.	20.6000	21.6203
218	3.60000	37.	20.9000	22.1657
219	3.60000	38.	21.0000	22.7112
220	3.60000	39.	21.5000	23.2567
221	3.60000	40.	22.0000	23.8021
222	3.60000	41.	22.5000	24.3476
223	3.60000	42.	23.0000	24.8931
224	3.60000	43.	23.5000	25.4386
225	3.60000	44.	24.0000	25.9840
226	3.60000	45.	25.0000	26.5295
227	3.60000	46.	26.0000	27.0750
228	3.60000	47.	27.0000	27.6204
229	3.60000	48.	28.0000	28.1659
230	3.60000	49.	29.0000	28.7114
231	3.60000	50.	30.0000	29.2568
232	3.60000	51.	31.0000	29.8023
233	3.60000	52.	32.0000	30.3478
234	3.60000	53.	33.0000	30.8932
235	3.60000	54.	34.0000	31.4387
236	3.60000	55.	35.0000	31.9842